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RESEARCH ARTICLE

Ocelot, *Leopardus pardalis* (Mammalia, Carnivora, Felidae), home range in the Lowland Atlantic Forest of Southeastern Brazil

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Abstract

The ocelot is an important Neotropical mesopredator and information on its spatial ecology remains scarce. Here we estimated the ocelot home range in a remnant of Lowland Atlantic Forest in Southeastern Brazil. The data were collected by camera traps installed at eight known ocelot latrines. We estimated the home range both based on the Minimum Convex Polygon (MCP) and the 95% adaptive Kernel density estimator (95%K) to compare with other published studies. We identified 22 ocelots (adult males = 8; adult females = 12; cubs = 2). Six males were recorded at more than one latrine, while all females were recorded at only one sampling point. In addition to male ocelots being recorded at a large number of points, they showed greater intrasexual spatial overlap as they used the same latrines, suggesting larger home ranges than females. The mean home range size for males was 12.1 ± SE 4.4 km^2 (range = 6.2 to 20.8 km^2) using MCP, and 19.9 ± SE 9.5 km^2 (range = 10.1 to 38.9 km^2) applying 95%K. Despite our estimates representing an approximation of the total area used by males, both values are consistent with those reported from other locations. Our data complemented the gradient of vegetation type sampled for ocelots in Atlantic Forest and support the suggestion that this environmental variable and, consequently, its effect on prey availability, influence the home range size of ocelot. Information on population ecology and other spatial ecology data are also presented.

Keywords

intrasexual spatial overlap, Kernel estimator, male home range, Minimum Convex Polygon, Neotropical felid, spatial ecology

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PENSOFT

Introduction

The ocelot, *Leopardus pardalis* (Linnaeus, 1758), is the largest of the spotted small cats in the *Leopardus* genus (mean = 11.6 kg; range = 8 to 17 kg; Gonçalves et al. 2018). The species has a wide geographical distribution, occurring from the Southern United States to Northern Argentina and Northwestern Uruguay (Murray and Gardner 1997). Ocelot inhabits a wide variety of habitats, including tropical (dry and humid) forests, marshy areas, mangroves, savannas, and dry scrub areas, typically occurring at elevations up to 1,200 m (Murray and Gardner 1997). The species is solitary and territorial, and deposits feces and urine in places (latrines) that increase the efficiency of marking territory and favor social communication (e.g. Emmons 1988; Moreno and Giacalone 2014), including information about reproductive status (King et al. 2017). Despite being a common feline and an important Neotropical mesopredator with a wide geographical distribution, estimates of the ocelot's home range are still scarce. In addition to the lack of information for several parts of its distribution, the studies applied different sampling techniques and approaches to data collection and used different methods for data analysis, resulting in non-comparable values (Gonzalez-Borrajo et al. 2016). The Atlantic Forest, one of the world's biodiversity hotspots, has only three home range studies for ocelots, all of them in the Southern portion of the biome (Di Bitetti et al. 2006; Goulart et al. 2009; Azevedo et al. 2019). Information on spatial ecology, including home range size, is crucial for understanding the intraspecific interactions and population dynamics of this species, helping to define wildlife management and conservation actions (Gonzalez-Borrajo et al. 2016).

The present study aims to estimate the home range of ocelots in a remnant of Lowland Atlantic Forest in Southeastern Brazil. In addition, information on population ecology and other spatial ecology data of the species are also presented.

Methods

Study area

The study was carried out at Vale Natural Reserve (Reserva Natural Vale - RNV; 19°06'S, 39°45'W and 19°18'S, 40°19'W), located between the municipalities of Linhares and Jaguaré, in the Northern portion of the state of Espírito Santo, Southeastern Brazil. The 22,711 ha of RNV connects with three other protected areas forming a continuous remnant of native vegetation: the Linhares-Sooretama Forest Block (Bloco Florestal Linhares-Sooretama – BFLS). Covering more than 53,000 ha, the BFLS represents about 11% of the remaining forest in the state (based on data available in FSOSMA and INPE 2021).

Most of the RNV is covered by dense lowland forest located on flat terrain (called Tabuleiro forest), and the local vegetation is classified as Perennial Seasonal Forest (Jesus and Rolim 2005). In addition to dense forest, the RNV presents a

local forest vegetation type growing on sandy soils (called Mussununga), native grasslands and flooded swamps, among areas with anthropic uses. The climate is tropical with dry winter (Aw, following the Köppen system; Alvares et al. 2014) and the mean annual temperature is 24.3 °C (Kierulff et al. 2014). The mean annual rainfall is 1,214 mm, with great variation between years (Kierulff et al. 2014). The RNV has a set of internal unpaved roads, which allow access to all parts of the reserve.

Data collection

The data were obtained using Bushnell digital camera traps (Model Trophy Cam HD Agressor) installed in eight latrines used by ocelots. The latrines were detected by active search and were characterized by the repeated accumulation of feces (and urine) in the same place over time. The selected latrines were distributed in different parts of the RNV (Fig. 1) and one camera trap was installed on tree stems in front of each latrine. The camera traps were adjusted to take two photographs and one video (20 seconds in duration) in each capture event. The interval between consecutive capture events was 10 seconds, and the camera traps operated 24 hours a day. Sampling was carried out from March 2018 to February 2019, totaling 12 months of study.

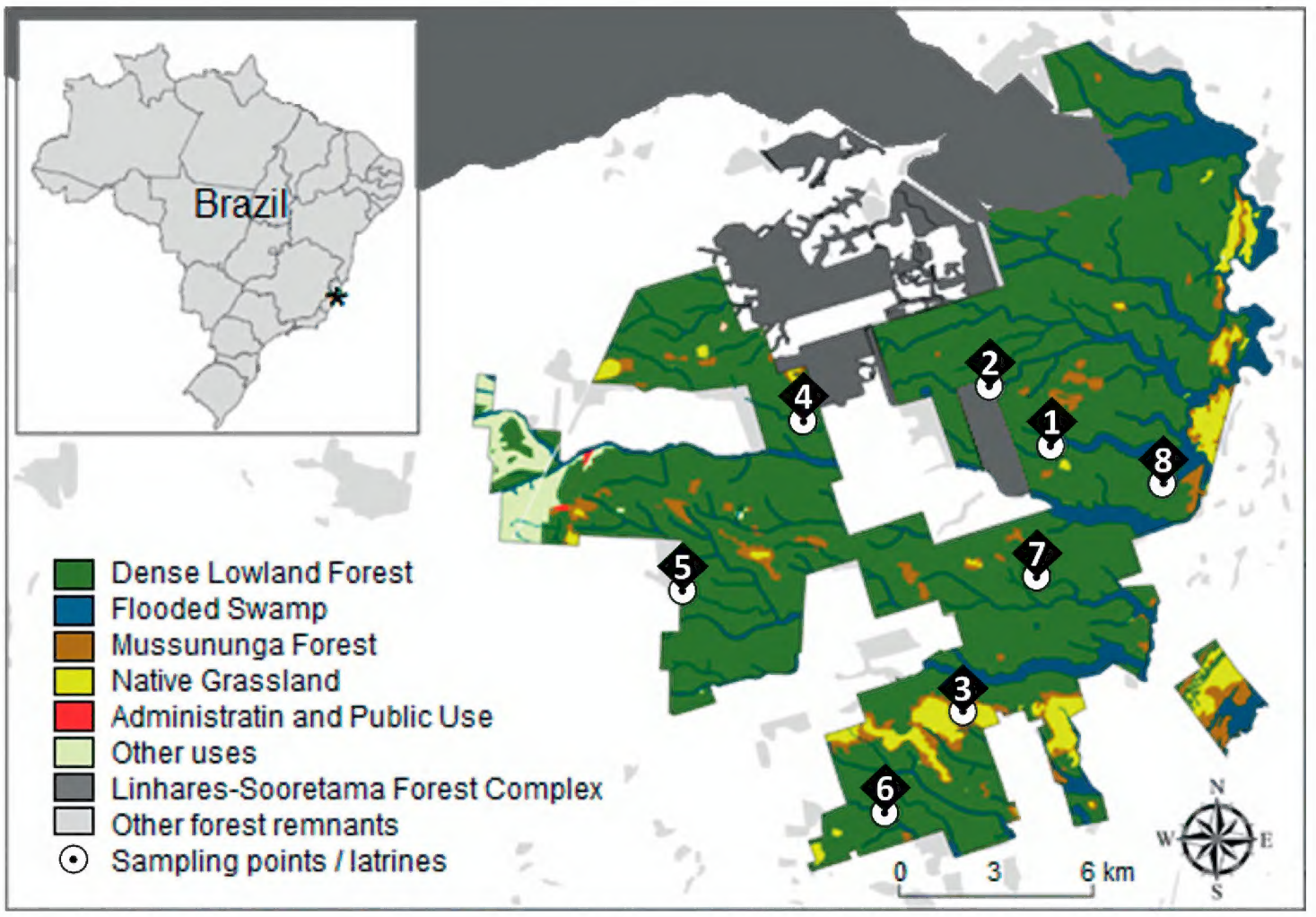

Figure 1. Vale Natural Reserve, part of the Linhares-Sooretama Forest Block, in the state of Espírito Santo, Southeastern Brazil, and locations of the eight monitored latrines.

Data analysis

Individual ocelots were visually identified based on specific coat patterns (spots and stripes). The sex of individuals was defined based on the visualization of external sexual characters in males (scrotum). The age of ocelots (cub, juvenile or adult) was determined according to the relative size of animals. Despite using only one camera trap per point, images of the right and left flanks of the individuals, as well as the sex and age identification, were favored by the time spent by ocelots in front of the camera trap interacting with the latrine (sniffing and defecating/urinating).

The home range was estimated only for adult individuals registered in more than two latrines. The home range size (in km^2) was calculated based on the 100% Minimum Convex Polygon (MCP) and the 95% adaptive Kernel density estimator (95%K) using the Standard Biweight (quartic) Kernel function. Both calculations were performed to compare with other published studies. The analysis was performed using the program OpenJUMP (version 1.7.1; Steiniger and Hunter 2013).

Results

We identified 22 individuals: eight adult males, 12 adult females and two cubs (siblings with undetermined sex). For two males, only the right flank was recorded, while the right and left flanks were recorded for the other six males. All identified females had both flanks recorded. The sex ratio recorded for adult ocelots was 1.0:1.5 (male:female). Males were recorded at all latrines and females at all but one. Thus, seven latrines registered individuals of both sexes (87.5%). Cubs were recorded at only one latrine (12.5%). The number of males recorded per latrine varied between 1 and 3 (mean = 2.1), and of females between 0 and 4 individuals (mean = 1.5). The number of males was greater than females at five latrines (62.5%), at two latrines the number of females was higher (25.0%), and at one latrine the number was the same (12.5%). Six males (75.0%) were recorded at more than one latrine, while all females were recorded at only one (including the female with two cubs). Three males were registered at more than two latrines (n = 3 latrines in all cases). The mean home range size for males was 12.1 ± SE 4.4 km^2 using the MCP, and 19.9 ± SE 9.5 km^2 using the 95%K (Table 1). The mean home range obtained with the 95%K estimator was 1.6 times greater than that generated by the MCP.

Table 1. Home range sizes (km^2) of male ocelots (*Leopardus pardalis*) using Minimum Convex Polygon (MCP) and 95% adaptive Kernel density estimator (95%K) in Vale Natural Reserve, Southeastern Brazil. The indication of the latrines where each individual was recorded is also shown (see Fig. 1 for details).

Ocelot ID	MCP	95%K	Latrines
Lp26	6.19	10.10	1, 2 and 4
Lp44	20.76	10.83	1, 6 and 8
Lp65	9.28	38.92	6, 7 and 8
Mean	12.08	19.95	-
Standard Error	4.43	9.49	-

Discussion

Male ocelots were recorded at a higher number of points and showed greater intrasexual spatial overlap considering the use of the same latrine in the RNV. Females, on the other hand, have lower intrasexual spatial overlap in the study area. Other studies have reported that males usually have larger home ranges than females, resulting in greater overlap between the areas used by males (e.g. Gonzalez-Borrajo et al. 2016; Azevedo et al. 2019). For females, the area used is determined by availability of food and pregnancy and parental care demands (metabolic demands), while for males it is also determined by access to females (Clutton-Brock and Harvey 1978). Emmons (1988) observed that pregnant and lactating ocelot females increased patrolling and marking behavior and seem to be less tolerant to territorial overlap with other females, probably to safeguard food resources. This territorial behavior can result in lower home range overlap between females throughout their lifetime, comparing to the overlap between males, even if there may be a considerable intrasexual overlap for both sexes in some cases. Intolerance to territorial overlap can be relaxed among females that know each other when they are not breeding (Emmons 1988). The relaxation of territoriality between familiar not breeding females may explain the use of one latrine by four adult females in RNV, including the female with cubs. Other authors also have suggested that the greater tolerance to territorial overlap between females may be due to the existence of some family relationship among them (Crawshaw Jr and Quigley 1989).

The proportion of male and female ocelots recorded by camera traps varies between samplings, with studies revealing a greater number of male (e.g. 1.0:0.6 - Pérez-Irineo and Santos-Moreno 2014; 1.0:0.7 - Azevedo et al. 2019) or female ocelots (e.g. 1.0-1.9 - Di Bitetti et al. 2006; 1.0:1.3 - Dillon and Kelly 2008). A previous study carried out at RNV registered a greater number of males than females (1.0-0.6 - Wolff et al. 2019), in contrast to the present study. In mammals, the sex ratio is influenced by life-history traits (species level), as well as social organization and dynamic interactions between sex roles (population level), which may explain the intraspecific variation across space and time (Kappeler 2017). We suggest that the difference in male and female proportion between Wolff et al. (2019) and the present study may also reflect the influence of sampling design on ocelot records between sampling periods (2013–2014 and 2018–2019, respectively). In this case, sampling latrines may have favored the recording of females, resulting in a sex ratio closer to the real abundance of both sexes in the population, because latrines are places used for direct and indirect intra and intersexual interactions. We suggest that latrines can be good locations for obtaining ocelot populational data.

Although the home ranges estimated in the present study represent only a portion of the total area used by the male ocelots, the values obtained in the RNV are consistent with those reported for the species. The ocelot home range sizes varied from 2 to 39 km^2 throughout its distribution and, based on meta-analysis, the

mean value was 17.4 ± SE 3.7 km² for the species, and 20.7 ± SE 6.1 km² for males (Gonzalez-Borrajo et al. 2016). The mean home range specifically for male ocelots in Atlantic Forest was 7.5 ± SE 4.8 km² (range = 2.7 to 12.3 km²) in Caraguatá Ecological Reserve (Santa Catarina state - Brazil; Goulart et al. 2009), 13.4 ± SE 8.0 km² (range = 3.2 to 37.1 km²) in Green Corridor (Misiones province – Argentina; Di Bitetti et al. 2006), and 32.9 ± SE 10.9 km² (range = 22.8 to 50.9 km²) in Iguaçu National Park (Paraná state - Brazil; Azevedo et al. 2019), using MCP in all cases. Only one previous study in the Atlantic Forest used 95%K, estimating a mean home range of 45.2 ± SE 4.9 km² (range = 34.3 to 63.0 km²) for male ocelots (Azevedo et al. 2019). Analyzing each method used to calculate the home range separately, our MPC estimate is close to the intermediate value previously reported, while the 95%K is almost half of the estimate available for the species in the biome.

Home range size may vary with an animal's sex and age and population density (Burt 1943) and is also influenced by environmental factors such as season and food availability (Dillon and Kelly 2008). The variation in local environmental factors makes the home range size variable also between ecoregions (Gonzalez-Borrajo et al. 2016). For Atlantic Forest, for example, the smallest mean home range for males was recorded in dense ombrophilous forest (Goulart et al. 2009) and the largest one was recorded in dense subtropical semi-deciduous forest (Azevedo et al. 2019). The vegetation in RNV (perennial seasonal forest) represents an intermediate typology between the ombrophilous forests and the semi-deciduous forests (Jesus and Rolim 2005), and we recorded an intermediate mean home range value for males (Fig. 2). These observations suggest that vegetation type (Dillon and Kelly 2008) and, consequently, its effect on food availability (due to changes in habitat productivity; Herfindal et al. 2005), may influence the home range size of ocelots. In this regard, the smaller home ranges would be associated to areas with high prey availability (e.g. Dillon and Kelly 2008; Moreno et al. 2012; Azevedo et al. 2019) supporting the theory that home range size can be inversely related to the availability of food items (Fig. 2).

Conclusion

The latrines demonstrated to be good locations for obtaining data on population and spatial ecology of ocelots, which may be associated with the fact of these locations are used for both intra and intersexual interactions. Although the home ranges estimated represent a portion of the total area used by males, the values obtained are consistent with those estimated for ocelots in other locations. The home range values presented here can be used as a reference for ocelots in RNV/BFLS and for lowland forest, contributing to the understanding of this biological parameter in the Atlantic Forest and for the species as a whole.

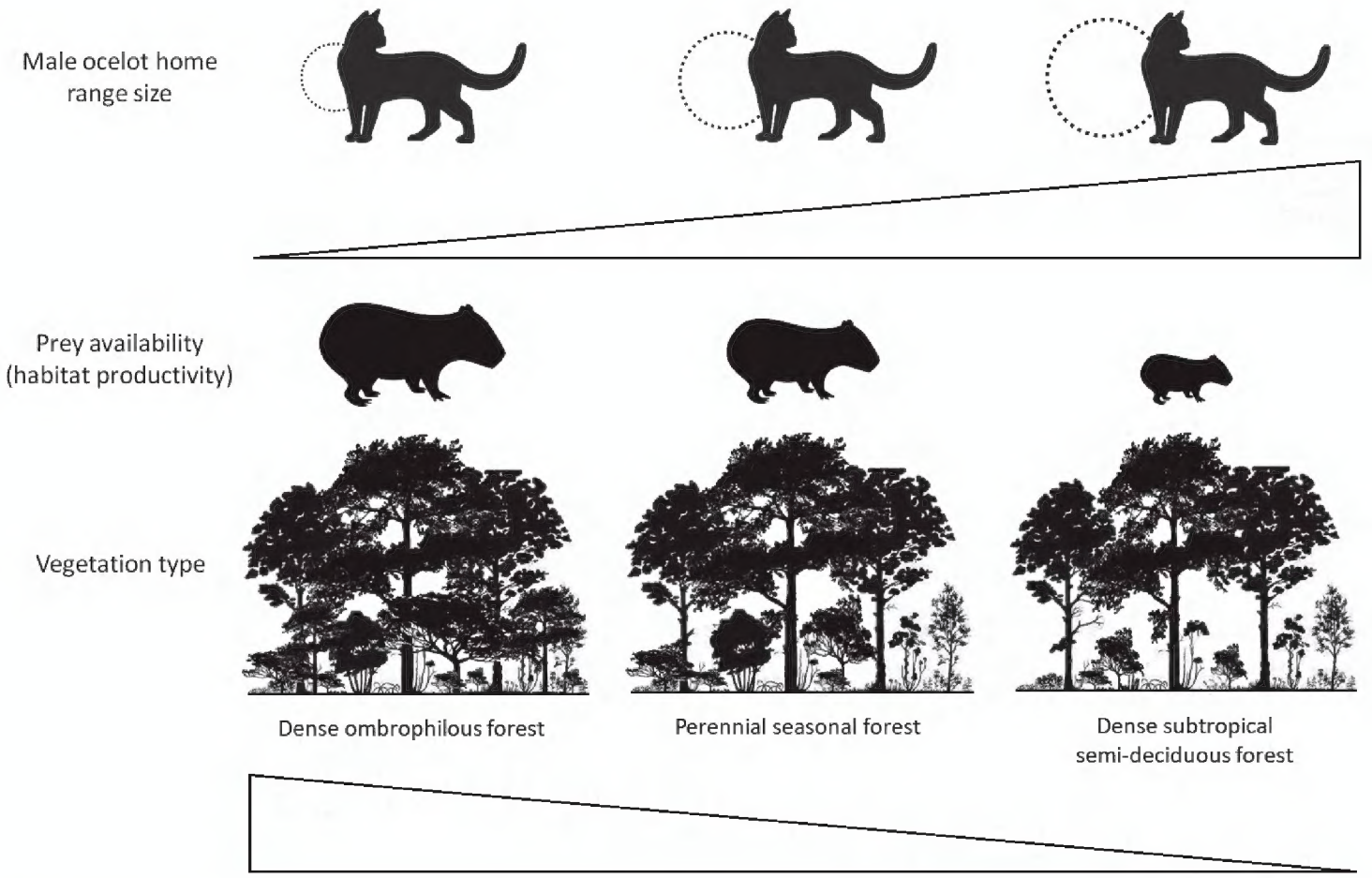

Figure 2. Gradient of vegetation type (structural complexity) and its effect on prey availability (habitat productivity) and home range size of male ocelots (*Leopardus pardalis*) in Atlantic Forest (inferences based on published data and in the data from the present study).

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